photometer, constitute contributions to the advancement of astronomy of which any investigator might well be proud, and which in themselves would afford ample ground for the award of this medal.

The foregoing brief narrative will, I trust, to some extent show the wisdom of our Board of Directors in awarding this medal to Professor PICKERING. Our medalist is still relatively a young man, and while his achievements have been vast, they are by no means ended, and we have every reason to believe that what has been done is but earnest of what will be done by him.

In the absence of Professor PICKERING, I request you, Mr. Secretary, to transmit this medal to the distinguished scientist to whom it is awarded, with the congratulations and best wishes of the members of this Society, that he may long live to enjoy his honors so fairly won.

THE CROCKER ECLIPSE EXPEDITION OF 1908 FROM THE LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA.

By W. W. CAMPBELL.

The Moon's shadow for the total solar eclipse of January 3, 1908, fell upon the Earth at sunrise in longitude 155° east and latitude 11° north, swept easterly across the central Pacific Ocean, and left the Earth at sunset on the western coast-line of Costa Rica. The shadow path crossed only two known landmarks—Hull Island, about seven hundred miles north of Samoa, and Flint Island (British), in latitude 11° south, four hundred and fifty miles northwest of the Island of Tahiti. The eclipse lasted sixty per cent longer and the Sun was much nearer the zenith at Flint Island than at Hull Island; and both were equally difficult of access.

On account of our position, on the Californian coast of the Pacific, and in view of our considerable experience in eclipse observation, there existed amongst astronomers a feeling that the Lick Observatory should, if possible, take care of this

eclipse. This feeling was intensified by the knowledge that no other observatory was planning to send out an eclipse expedition. Our duty in the matter was in harmony with the strong desire to maintain, as far as practicable, the continuity of our eclipse series of observations, and to undertake the solution of certain definite eclipse problems.

The subject was brought to the attention of Mr. WILLIAM H. CROCKER early in the year 1907, and he generously undertook to defray the expenses of an expedition to Flint Island—the ninth Crocker Eclipse Expedition—provided a practicable method of transport could be found. There is excellent steamer service between San Francisco and Tahiti; but Flint Island is not on any steamer route. Regular steamers in the South Seas could not be induced, even for a consideration, to go a few hundred miles out of their way, because of insurance complications and of government mail contracts on fixed schedules and over definite routes. The chartering of a steamer exclusively for this purpose was prohibited by the cost. At this juncture it seemed to me that an appeal might with propriety be made to the Navy Department of our Government to transport the expedition. President WHEELER was pleased to approve this plan and to present my appeal. In response, the department expressed its desire and readiness to meet our requirements fully. It was arranged that the U. S. gunboat "Annapolis," under command of His Excellency, Captain C. B. T. MOORE, U. S. N., Governor of Tutuila, Samoan Islands, should meet us at Tahiti, transport the expedition to Flint Island about four weeks before the eclipse, and, two days after the eclipse, re-embark and carry the expedition back to Tahiti. It was my first pleasure and duty, on returning from Flint Island, to express to the department not only our thanks for this invaluable service, but our admiration for the clear-cut and business-like manner in which Governor MOORE and his staff carried out the letter and the spirit of the department's instructions.

It seemed very desirable that the observing programme should include a study of the heat radiations of the corona, by means of a bolometer. This important line of investigation had been inaugurated at the eclipse of 1900 by Mr. C. G. ABBOT, of the Smithsonian Institution Observatory. This

fact, and his extensive experience and recognized skill in the use of the bolometer, made him the logical and best observer for this eclipse work. Accordingly, in April, 1907, it gave me pleasure to urge upon Dr. WALCOTT, Secretary of the Smithsonian Institution, and Director ABBOT, of the Astrophysical Observatory of the Institution, the desirability of dispatching an expedition to secure these observations, and to invite the suggested expedition to share in the travel and subsistence arrangements already under way for the Lick Observatory expedition. The proposal met with their approval. The scientific plans of the two expeditions were to be essentially independent, the travel and subsistence expenses to be shared on the basis of the number of persons in the two parties.

Professor E. P. LEWIS, of the Department of Physics, University of California, was invited to join the Crocker Expedition by virtue of his great skill in spectroscopic researches, in order that he might photograph the spectrum of the corona with his large quartz spectrograph.

The two expeditions sailed from San Francisco on November 22d, on the steamship "Mariposa," of the Oceanic Steamship Company. We numbered eight persons, and there were thirty-five tons of scientific instruments, tents, food, lumber, and general supplies. The party consisted of Director and Mrs. CAMPBELL, Astronomers PERRINE and AITKEN, and Assistant ALBRECHT, of Mt. Hamilton; Professor LEWIS, of Berkeley; Director ABBOT, of Washington, and his assistant, Mr. A. F. MOORE, of the University of California.

The twelve-day passage to Tahiti, in latitude 17°.5 south, was comfortable, but without special incident, as no ships were sighted after the second day out, and no land until the eleventh day, when three very interesting islands of the Paumotu group, or Dangerous Archipelago, were passed.

We reached Papeete, Island of Tahiti, on December 4th. The "Annapolis" came into the harbor on the morning of December 5th. By invitation extended through Governor MOORE, our party was joined on board the "Annapolis" by Professor BENJAMIN BOSS, in charge of the U. S. Naval Observatory at Pago Pago, formerly assistant in the observatories at Washington and Albany. Three busy days in Papeete

were devoted to transferring our freight to the warship, securing a supply of mineral drinking-water, fruit and other perishables, a surf-boat for landing, and picking up our Tahitian carpenter, cooks, and laborers. We sailed for Flint Island on the evening of December 7th.

We approached Flint Island at noon on December 9th, with very considerable anxiety. On the "Mariposa" and in Papeete we heard much of the difficult and dangerous surf landing. The captain of the Tahiti schooner which runs to Flint Island about twice a year explained that landing was possible at only one point, on the northwest side, where a narrow and shallow passage into the flat coral reef had been blasted out; and if the surf were running high at that point we must wait on-board-ship until it subsided. This was true even when the surf-boats carried nothing more valuable than gunny-sacks full of cocoanuts and copra. The situation could be more serious for scientific instruments.

The visible parts of Flint Island are entirely of coral construction. The waves break on the outer edge of a flat and level reef, whose average width is perhaps two hundred feet, whose height appears to be closely that of quiet water at high tide, and which nearly or entirely surrounds the island. At the outer edge the dip of the reef into deep water is remarkably steep. Sloping up from the inner edge of the flat reef is the dazzling white beach of broken coral, perhaps one hundred feet wide, which encircles the island, except that on the east side there are many irregularities in the way of rough and tilted reefs of solid rock not covered by broken coral. The entire area inside of the white beach consists of broken coral, more or less disintegrated, and is densely covered with trees. The form of the island is roughly that of a lozenge or kite, with greatest width east and west, nearly one mile, and length north and south slightly over two miles. Its greatest height, above mean sea-level, is twenty-two feet at the point, near the landing, where the buildings of the leasing company are situated. The average height is said to be thirteen feet.

A few years ago the northern four fifths of the island were cleared of native trees and planted to cocoanut trees. There are no settled inhabitants. The lessees, Lever's Pacific Plantations Limited, maintain there an English manager and

about twenty-five native men and women, all engaged exclusively in the manufacture of copra.

The capable manager, Mr. E. F. HAWK, rowed out to the "Annapolis" with the pleasing intelligence that in his twenty-seven months' residence on the island he had never seen the surf running lower. Accordingly, with the help of the native boatmen and laborers, and of many of the ship's men, the landing in the surf-boats was rushed. By eight o'clock our forty tons of effects were on the beach and the "Annapolis" had turned back to Tahiti. The contents of our more than three hundred numbered packages were known in detail. This fact, and the placing of the large veranda and several rooms of the manager's bungalow at our disposal, made the starting of life on the island easy. It would be a dull imagination indeed which, at our first dinner, should not travel rapidly, to the accompaniment of roaring surf, the great cocoanut grove filled with nuts and noisy birds,[1] native figures moving noiselessly about, and the knowledge that a month of strenuous and interesting labor had begun.

The site for the station was selected at a point about two hundred feet directly east of the manager's bungalow, in the midst of the cocoanuts; a few missing trees here and there affording just sufficient unobstructed sky for convenient adjustment of the eight groups of instruments. The soil, of old coral, was, nearly everywhere in our camp, covered with rich grass. A tramway running from the landing slip immediately past the camp-site greatly facilitated the bringing up of our heavy supplies. The iron-roofed buildings, and the plantations' and our own steel tanks, affording, to our relief, an abundant supply of pure drinking-water, were less than one hundred yards away. The surrounding forest made an efficient break against winds from all directions; but, fortunately, the wind that rustled the treetops extended its cooling effects to the observers at their work. We were eight hundred and thirty feet (the meridian of the transit instrument) from the outer edge of the reef, and the altitude of the site was sixteen feet above mean sea-level. The ridge, altitude twenty-two feet,

[1] The old native name for Flint Island was Manuai, meaning "birds' resting-place." It is the home of tens of thousands of sea-birds, principally black terns, white terns, and frigate birds. Their chatter never ceased.

bearing the bungalow and the copra houses, was between us and the beach. The terrible hurricane of 1906 had brought the seas up to the crest of the ridge, throwing some of the buildings off their foundations, but the waves did not reach our position. This was comforting, inasmuch as the great loss of life and property caused in the South Seas by the hurricane is still the prevailing topic of conversation in that region. The sky when clear was remarkably pure and blue, resembling the Mt. Hamilton sky at its best. All in all, the conditions at the station, local and general, were better than we could have expected, though we were always conscious of the fact that the chances for clear sky at the critical time were not greater than two out of three.

As a result of prior correspondence with, and at the suggestion of, the American Consul at Tahiti, it was planned to provide cocoanut-thatch huts for the living-rooms, dining-room, kitchen, etc. Lumber for their frames, taken from San Francisco, was quickly put in place by our carpenter and helpers; and the natives brought cocoanut fronds, wove them into thatch, and fastened them on the roof- and side-frames. The eight houses were completed, furnished with the necessary shelves and tables, and occupied as rapidly as each was completed,—all in four days. They were so easy of construction, so comfortable in tropical sun and rain, in fact so thoroughly adapted to their purposes, that the publication of a few additional details may be of value to future expeditions in tropical locations where thatch is available.

Each of the six sleeping-huts was 10 x 14 feet, with side-walls 7½ feet high. The gable roof was slightly steeper than an ordinary shingle roof. The thatch on the roof should be spread thickly, to turn the rain, but the walls need only a one-thickness covering. We found it advantageous to leave open the two side walls between the limits 6 feet and 7½ feet above the ground, as this afforded better air circulation. A strip of cloth suspended by and sliding on a wire served as a door. Good dimensions for timbers are: Six side-posts, 3 x 3 inches, let into the ground a short distance; two gable-posts and one door-post, 2 x 3 inches, also let into the ground; two side-beams, 3 x 3 inches (with allowance for one-foot gable-roof projections); three cross-beams, 2 x 3 inches; six rafters on

each side, 2 x 3 inches (with allowance for one-foot eaves); one ridge board, 1 x 6 inches; two boards on the lower ends of rafters, 1 x 4 inches. Total, 160 feet, board measure. Diagonal ties in the wall and roof sections, of soft steel wire, $^1/_{16}$ inch, can be put in place, with six-penny nails, in a few minutes. The natives are accustomed to fastening the thatch in place with strong wrapping twine, but we found six-penny nails more satisfactory in every way. Each hut accommodated the large cots, baggage, and conveniences for two men.

The dining-room, 12 x 28 feet, had a thatch roof and gables, and mosquito-netting ceiling, walls, and doors. Double-door entrances, such as are used in connection with dark-rooms, would have been an improvement in keeping flies out.

On a similar occasion we should construct two work-rooms, in the same manner, with thatch roofs and open sides, and also a food-supply hut.

While the huts were in process of building, the pier for the Repsold altazimuth was constructed and the instrument mounted thereon ready for use; the first time observation having been secured on the evening of December 11th. The grounds were cleared, the instruments and supplies were unpacked in the canvas tents, and the foundations were made ready. The weather was fine, barring short rains, during the first twelve days on the island, and the work of assembling, erecting, and placing the instruments in approximate position and adjustment was well along toward completion. In fact, there remained essentially only the final and delicate adjustments, the repeated trials of the instruments, the training of the observers, and the thousand and one changes in details which go to make up the difference between reasonably good results and those that are really worth while.

The Smithsonian Expedition's observing station was selected by Director ABBOT at a point on the beach about 1,200 feet northwest of ours, in order that his bolometric observations prior to the eclipse might have one half the sky unobstructed by trees. The progress of Mr. ABBOT's preparations was analogous to our own.

A few weeks before leaving California we learned with great pleasure that Mr. FRANCIS K. McCLEAN, F. R. A. S., of Tunbridge Wells, England, son of the late F. K. McCLEAN,

F. R. S., distinguished contributor, both scientifically and financially, to astronomical progress, would conduct an expedition to Flint Island at his own expense. We looked forward to his coming with eagerness. His chartered ship arrived on December 23d. The party consisted of Mr. McClean, chief; Messrs. Brooks, Raymond, and Short, of Sydney; and Messrs. Walker and Winkelmann, of Auckland. Their camp adjoined ours on the southeast. We found them to be helpful and congenial neighbors, and we were sorry to lose their companionship on January 3d, immediately following the eclipse. Their photographs were to be developed on ship-board. We have not learned as to the degree of their success, but we trust that Mr. McClean is well satisfied with the results of their worthy and hard work. Mr. McClean most kindly brought Mr. Merfield, of the Sydney Observatory, to assist our expedition.

The days following December 20th were for the most part cloudy, but the nights after December 25th were nearly all clear. The preparations, proceeding at a normal rate, were completed in good time on the morning of January 3d. The "Annapolis" returned on the early morning of January 1st, bringing Consul and Mrs. Dreher from Tahiti to assist in the observations, and an abundant supply of ice for the photographic work.

A room in the bungalow was fitted up as a dark-room. This had been placed at our disposal by Manager H. Mortimer, who had succeeded Manager Hawk on December 19th. Mr. Mortimer was invited to assist in the observations.

The forenoon of January 3d was alternately clear and cloudy, with the clearness much in excess. About ten minutes before the eclipse was total, clouds formed rapidly, until the sky was densely covered. Just as the time-keeper called from his chronometer, "Five minutes before totality," a drenching rain fell, and all seemed lost save honor. At the end of two or three minutes the rainfall began to decrease and the clouds in the east gave signs of breaking. The signal "two minutes before totality" was called, as prearranged. Less than a minute before totality the slender crescent of the Sun showed faintly through the clouds, though a moderate rain was still falling. The rain and clouds grew rapidly lighter,

and the last drops fell at two or three seconds after totality began. Immediately after the beginning of totality the corona was faintly visible through the thin clouds. These continued to disperse rapidly. During the second quarter of the total phase the clouds were extremely thin, though a thicker cloud obscured the Sun near the end of the second quarter; and during the third and fourth quarters the sky was clear of clouds, but a thin haze could be distinguished. There was no wind.

About ten seconds before totality, the rain having nearly ceased, the order was given to the workman seated on top of the outer of the two towers supporting the forty-foot camera to remove the tarpaulin from over the lens. The order was executed promptly and the remnant of the Sun's crescent was first seen by the observer inside of the camera just one second before totality, and he immediately called out "One second before."[1] The signal "Go!" was called by the observer at the instant when the crescent disappeared. Such of the instruments as were still covered, awaiting the end of the rain,—for example, the larger cœlostat,—were uncovered within a few seconds, and the programme of observations was thenceforth carried through without a single slip. The twenty instruments, driven by seven clocks, and the eleven observers and two helpers did their work to perfection. Two spectrographic exposures planned for the twelve seconds immediately preceding totality were necessarily omitted, and some of the sensitive plates were thought to be damaged by getting wet in the sudden downpour. The remaining exposures were expected to give good results; and such proved to be the case when the plates were developed, during the following two nights. All of the instruments were in perfect focus and adjustment.

This eclipse was a very "light" one,—not nearly so dark as those of 1898, 1900, and 1905, as observed by the writer.

The accompanying views of the station are from photographs secured shortly after the eclipse was over. The negative of the group of observers was unfortunately much underexposed. The

[1] It had been arranged that this observer should call out "Forty-eight seconds before" and "Nineteen seconds before [totality]" when the uneclipsed crescent had certain definite computed lengths; but the impossibility of uncovering the lens while the rain was still falling prevented the giving of these signals.

canvas covering of the outer tower supporting the forty-foot camera was removed before photographing that instrument.

The repacking of the instruments proceeded rapidly, and, the surf being very favorable, the most valuable articles, such as chronometers, lenses, mirrors, prisms, and clocks, were put on-board-ship on the morning of January 4th. As soon as the last of the eclipse negatives was dry all were packed with extreme care and sealed in tin. These packages, accompanied by the observers in two surf-boats, were the last to go on board, at 11 o'clock of January 5th. By this time the surf had risen, one of the boats shipped considerable water, and the experiences of both boats in passing out through the surf were certainly exciting. The "Annapolis" headed at once for Tahiti, which we reached at daylight of the 7th.

Our departure from Flint Island was not unmixed with regret. A few members of the party were heard to wish that they could remain longer to enjoy the wonderful beauty of our surroundings, a result that strenuous eclipse duties did not adequately permit. Our camp-life was wholly devoid of unpleasantness. There had been time on a few evenings for experiences that will never be forgotten. A successful turtle hunt on the coral beach, in alternating moonlight and tropical downpour; a Christmas-tree, with presents and toasts supplied by friends who remained behind in Papeete; a Christmas dinner in which Mr. McClean's party and ours joined forces; and a poetic contest entered into by nearly all members of both parties, to determine who should be called the Poet Laureate of Flint Island. Every member of the party was well every minute, notwithstanding exposure to tropical sun and frequent drenchings; and this happy result is perhaps sufficient comment on the judgment and efficiency of the commissary department.

Six days on the Island of Tahiti were devoted to closing up the local business affairs, to observing for longitude at Point Venus, to sight-seeing, and to several exceptionally agreeable social matters. We sailed north on the 13th, and after a stormy passage entered the Golden Gate on the 25th. The instruments and eclipse photographs reached Mt. Hamilton uninjured early in February.

Following is a brief description of the instruments, observing programme, and results secured. The results obtained with

each instrument and for each problem will be published later in detail.

TIME, LATITUDE AND LONGITUDE.

It was the intention that Dr. AITKEN should observe Moon culminations both before and after the full Moon of December 19th, with the Repsold altazimuth instrument, to determine the longitude of the station; taking into account the fact that the Moon's right ascension, as measured at Mt. Hamilton on four nights in October and November by Professor TUCKER, was $0^s.41$ greater than the ephemeris value. Unfortunately, there were thick clouds at the times of transit on some ten successive nights, and only one culmination was observed,—on the night of December 25th. The resulting value of the longitude, $10^h\ 7^m\ 10^s.0$ west, is necessarily of small weight. Our two chronometers, transported from the clock of the Students' Observatory, Berkeley, to Flint Island, and back to the clock in Berkeley, gave a longitude of $10^h\ 7^m\ 11^s$ west. A comparison of time observations by transits secured on January 3d, at the eclipse station, with sextant observations of the Sun obtained at Point Venus, Tahiti, on January 8th, made the longitude of our station $10^h\ 7^m\ 16^s.8$; assuming the position of Point Venus to be as quoted in the "Connaissance des Temps."

Dr. AITKEN'S observed meridian altitudes of a considerable number of stars on two evenings gave results for the latitude as follows:—

December 13th,	$-11°\ 25'\ 26''.6 \pm 0''.62$
December 26th,	$-11\ \ 25\ \ 27\ .1 \pm 0\ .41$

The adopted co-ordinates of the instrument, located near the center of the groups of instruments, are:—

Longitude........	$10^h\ 07^m\ 13^s$ W. $\pm 4^s$
Latitude..........	$-11°\ 25'\ 26''.8\ \ \pm 0''.4$

The concrete pier was left standing. The entrance to the landing-slip in the reef is estimated to be 1,200 feet northwest of the pier.

Throughout totality the second-beats of the chronometer were called off by Dr. AITKEN, as guides to the observers in the Lick and British parties.

TIMES OF BEGINNING AND ENDING.

The predicted times of beginning and ending of totality, based upon American Ephemeris data, and the adopted longitude and latitude of the station were:—

Beginning,	9^h	22^m	43^s	Greenwich mean time
Ending,	9	26	44	" " "

The times observed by Dr. AITKEN without telescopic assistance, and by Dr. ALBRECHT inside of the forty-foot camera, agreed within a second, and were:—

Beginning	9^h	22^m	20^s
Ending	9	26	12

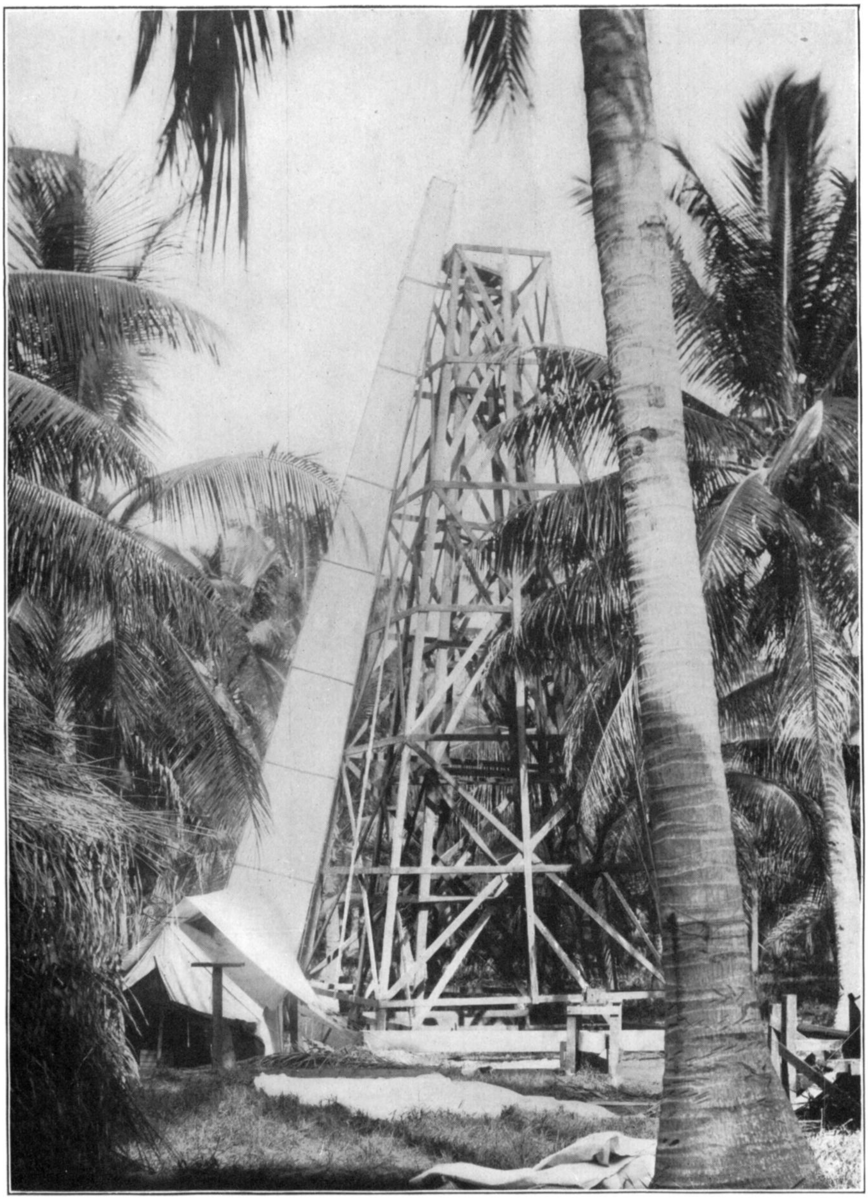
The observed duration, 3^m 52^s, was 9^s shorter than the predicted duration; and mid-totality came 27^s ahead of the predicted time. The observed excess of the Moon's right ascension, referred to above, would account for fully 20^s of the advance. The remaining few seconds are no doubt due to additional slight errors in the assigned positions of the Sun and Moon, and possible small errors in our adopted longitude.

THE FORTY-FOOT CAMERA.

This camera was erected under the personal supervision of Mr. CAMPBELL, the adjustments were made by Messrs. CAMPBELL and ALBRECHT, and the observations were secured by Dr. ALBRECHT.

"The outside general features of this instrument, designed by Professor SCHAEBERLE for observing the eclipse of 1893, are shown in the reproduced photograph of the station. In this camera the Clark lens of five-inch aperture, the combination tube of iron and cloth, and the plate-carriage moving by clock-work on an accurately curved metal track, are supported entirely independently of each other. The lens is mounted on the top of a strong interior tower, surrounded by a cloth-covered outer tower, whose duties are to support the upper end of the camera tube and to prevent the wind from shaking the inner tower; a system of lens support devised by Mr. CAMPBELL to meet conditions on the plains of India in 1898. With this form of support the camera can easily be pointed near the zenith if necessary (as in Sumatra by Mr. PERRINE in 1901); and the advantage[1] of having the lens at a good height above the radiating soil is preserved. The towers

[1] A comparison of results obtained with the tower and horizontal forms of telescopes at the Solar Observatory, Mt. Wilson, in 1907, is strongly confirmatory of this advantage.



THE 40-FOOT CAMERA.

are easily constructed, the various parts of the camera are quickly put into their approximate positions from simple computations, and the final adjustments are readily made."—*Extract from the Lick Observatory-Crocker Eclipse Expedition to Spain, in 1905. Publications A. S. P., February, 1906.*

Lumber for the towers and cement for the footings were taken from San Francisco. They were constructed at the expense of two days' labor. The focal length being 40.00 feet, and the Sun's altitude at mid-totality being 73° 58′, the center of the lens was placed 38 feet 5.35 inches higher than the center of the sensitive plate, and 40 feet above the ground under the towers. The tent covering the traveling plate-carriage was set in a pit excavated for this purpose to a depth of fifteen inches. The excavation was made only in order that firmer soil to support the carriage might be found.

Excepting the work of our expeditions, nearly all large-scale coronal photography of the past ten years has used horizontal cameras, with cœlostats to reflect the coronal radiations into them,—following the re-invention of the cœlostat by LIPMANN in the middle nineties. While the cœlostat has evident advantages in certain spectrographic and other researches on the Sun, or bright bodies lying near the celestial equator, its use in large-scale coronal photography has always seemed to us to be unwise. That a horizontal camera is slightly the more *convenient in construction* is true, but this item is entitled to no consideration if another form of camera is *better*. The factors of chief significance appear to be as follows:—

1. The tower camera has its lens and its tube at a good height above the radiating soil; all parts of the horizontal camera are near the soil. The "seeing" with the former should be the better.

2. The tower is the more readily ventilated shortly before totality occurs. (The plate-holder tent is always protected from direct solar radiation on the day of the eclipse by tent flies or fresh foliage. Canvas protection for the white-canvas camera-tube could readily be provided if thought desirable.)

3. The tower camera has the simpler optical equipment; the introduction of extra optical pieces and surfaces, such as the cœlostat mirror, is always to be avoided, other things being equal.

4. The focus of the tower lens remains practically constant; the focus of the cœlostatic optical train usually changes rapidly with changing temperature—and the temperature can be expected to fall rapidly during the hour preceding totality.

5. Driving-clock errors and irregularities are not magnified in the Schaeberle tower camera; such errors and irregularities in a large cœlostatic camera are magnified greatly on the sensitive film.

6. The lens in the Schaeberle tower camera is collimated for the Sun at mid-totality; but the lack of collimation at the beginning and ending of totality appears to be negligible even for eclipses of long duration, with the lens of aperture 5 inches, and focal length 480 inches—ratio 1 : 96.

7. It is probably as easy to protect the inner tower as the cœlostat against wind vibrations.

Six exposures were made with the forty-foot camera, on Seed plates, No. 27, as below:—

Exposure	No. 1	4 seconds
"	No. 2	2 "
"	No. 3	32 "
"	No. 4	16 "
"	No. 5	64 "
"	No. 6	32 "

Returning sunlight fell on the last plate for a fraction of a second. The seeing was splendid, the focus and clock-driving were perfect, and the negatives are excellent. A reduced copy of No. 4 is reproduced in the illustration. The diameter of the Moon's image on the original negatives is 4.74 inches. It is scarcely necessary to say that the rich detail of the original is largely lost in the half-tone print. Two of the negatives have "standard squares" near one edge, made by exposing the squares to the light of a Hefner amyl-acetate lamp on the night preceding the eclipse.

THE FLOYD CAMERA.

This camera, with Clark lens of 5-inch aperture and 67-inch focal length, had for its purpose the recording of the corona on a small scale, giving images especially valuable in the study of the mid- and outer-coronal structures. It was mounted

horizontally and received its light from a part of the 12-inch cœlostat mirror. Mr. CAMPBELL attended to the mounting and adjustments, in connection with the difficult placing and adjusting of the large moving-plate spectrograph, which received its supply of light from the same mirror.

The exposures were made on eclipse day by Mr. MORTIMER, on Seed plates, No. 27, as follows:—

No. 1	Short as possible
No. 2	1 second, when ready
No. 3	2 " " "
No. 4	4 " " "
No. 5	8 " " "
No. 6	16 " " "
No. 7	8 " at $3^m\ 30^s$
No. 8	2 " when ready

The exposures did not begin immediately following the beginning of totality, as the cœlostat covering was not removed until after the last drops of rain fell. The negatives are all of great excellence. The longer streamers are recorded out to two solar diameters. The general form of the corona is shown in the reproduction of negative No. 6, but the exquisite detail of the original is lost.

The longer streamers are rather uniformly distributed around the Sun, but the strong inner corona is considerably stronger in the east and west than in the polar regions. The 1905 inner corona was about equally strong in the equatorial and polar regions.

POSSIBLE CORONAL EXTENSIONS.

It was the special duty of Consul DREHER to look for and determine the positions and lengths of possible coronal streamers of great extent, such as those observed by Professor NEWCOMB at the eclipse of 1878. No extensions greater than those recorded on the Floyd negatives were visible. Dr. PERRINE was also to look for the same phenomena. The slight changes in the other parts of his programme, made necessary by the rain, curtailed the time assigned for the observations just referred to, but in the short interval that was available he saw no long extensions.

THE INTRAMERCURIAL-PLANET CAMERAS.

The search for possible intramercurial planets was continued by Dr. PERRINE on essentially the plans used at the eclipses of 1901 and 1905. There were eight cameras, provided with Clark lenses of 3-inch aperture and 11-foot 4-inch focus. Four of these cameras, using plates 18 x 22 inches, were fastened together rigidly, and so mounted on a clock-driven polar axis that they covered a region 28° long, in the direction of the Sun's equator, by 9°.25 wide. Another set of four cameras, using plates 16 x 20 inches, were similarly mounted, so as to cover the same region as the first group, excepting a narrow strip around the edge of that region. Both groups of these cameras, and the group of polarigraphs, are shown in the illustration.

One plate was exposed in each camera during the last three minutes of totality. Duplicate exposures were thus obtained for each of the four areas into which the region was divided. One of the groups of cameras was set up on Mt. Hamilton in October, before starting to Flint Island, and duplicate exposures of precisely the same region were obtained after sunset. The four sets of negatives furnished sure and convenient means of determining whether objects on the plates were stars, planets, or defects.

These cameras and their driving-clocks worked perfectly. In the sudden downpour of rain immediately preceding totality it was not possible to protect everything, and a little water got into these instruments. Some of the negatives are marked by narrow bands where the rain-water ran across them. Until after our return to Mt. Hamilton it was thought that the photographs were damaged to such an extent that the value of the intramercurial search would be seriously impaired; and our public announcements embodied this view. It is gratifying to announce, as a result of Dr. PERRINE's preliminary examination of the plates, that these fears were groundless. He has found the images of fully three hundred stars on the photographs, down to the ninth magnitude; and, surprising to relate, the rain-streaked areas contain the images of all the known stars that he expected to find therein. All images have been identified as those of well-known stars. The search has not been finished, but the expectation of finding images of unknown bodies is small

COCLOSTAT, MOVING-PLATE SPECTROGRAPH AND FLOYD CAMERA.

indeed. In my opinion, Dr. PERRINE'S work at the three eclipses of 1901, 1905, and 1908 brings the observational side of the famous intramercurial-planet problem definitely to a close. It is not contended that no planets will be found in the intramercurial region: it would not be especially surprising if small ones should be discovered at some future time; but it is believed that their mass would be inadequate to disturb *Mercury's* motion.

Professor BENJAMIN BOSS was an efficient assistant to Dr. PERRINE in mounting these cameras and in securing the observations.

THE MOVING-PLATE SPECTROGRAPH.

The spectrograms obtained at the eclipses of 1898, 1900, and 1905, on a continuously moving plate, showed that this is a most advantageous method for recording the changing spectrum of the Sun's edge as the edge is gradually covered or uncovered by the Moon. The dispersive power was supplied in 1898 by a plane grating, and at the other eclipses by two 60° prisms. The instrument used at Flint Island is shown in the illustration. The light, supplied by a part of the cœlostat mirror, passed through three 60° prisms, whose circular apertures are 2⅛ inches, and thence through the camera lens, of 60-inch focus, to the plate. The cœlostat may be seen, in the photograph, under the camera-box section of the spectrograph, and the first prism is visible to the right of the cœlostat. The entire spectrograph was so mounted that it could be rotated about the axis of the light-beam incident upon the first prism-surface, in order to place the prism-edges parallel to the central elements of the uneclipsed thin crescent near the beginning and near the ending of totality. The central sections of the crescents in the cœlostat images made angles of 27° 06′ and 6° 18′, respectively, with the horizon. The instrument was placed in its computed position by means of a theodolite, and the spectrum on the day of the eclipse fell upon the sensitive plate in the desired position, as nearly as could be estimated.

Immediately in front of the plate was a slit $^1/_{16}$ inch wide, which permitted the central section of each crescent in the spectrum to fall on the plate. A motion of approximately $^1/_{16}$ inch per second was given to the plate by the piston on the plate-holder slide. The piston was operated by a weight.

The linear dispersion is such that the region λ 3700 to λ 5300 covers 13 inches. The focal surface is strongly curved; the tangent at the center of the field lying ¾ inch outside the focal positions at the ends. A film 7 x 14 inches was used. A special plate-holder held the film firmly in position.

An exposure extending from fifteen seconds before to fifteen seconds after totality began was planned for, but omitted on account of the rain. The mirror was not uncovered until some five seconds after totality began. A corresponding exposure was made at the end of totality, with entire success, save that the negative is somewhat overexposed. The photograph is in good focus, from λ 3800 to λ 5100. Hundreds of bright lines are recorded in lengths and at times showing the thickness and locations of their corresponding vapor strata, and their changes into dark lines as the photospheric surface was uncovered by the Moon. The photograph contains a mine of information as to the structure and composition of the Sun's higher atmosphere. The series of four photographs may be said to constitute the basis for a study of the stratification of the Sun's atmosphere.

THE THREE-PRISM SPECTROGRAPH.

A spectrograph of high dispersion, containing three very dense glass prisms, was used in the hope of recording the green coronal line, in order to determine its wave-length with great accuracy. The solar spectrum was impressed upon the plate immediately after the end of the total eclipse, for reference. No trace of the coronal line exists on the plate, undoubtedly because of the strong absorption of the prisms. As is well known, there are no available plates very sensitive to light of wave-length λ 5300.

THE SINGLE-PRISM SPECTROGRAPHS.

Two single-prism spectrographs were designed by me for efficiency in recording the continuous spectrum of the corona. These and the three-prism spectrograph described above were mounted on one clock-driven polar axis, as illustrated. All were adjusted with great care by Dr. ALBRECHT, and the programme of observations at the time of the eclipse was carried out perfectly by Mr. MERFIELD. The slits of all the instruments extended east and west centrally across the Sun's image.

THREE-PRISM AND TWO ONE-PRISM SPECTROGRAPHS.

One of the single-prism instruments, using a Seed plate No. 27, was exposed from $0^m\ 5^s$ to $3^m\ 51^s$. The spectrum is recorded for the inner corona, from λ 3600 to λ 5350, and in the blue region it extends out to at least 15 minutes of arc on each side of the Moon. The recorded spectrum, in fact, extends outward more than a solar diameter on each side, corresponding to the full length of the slit; and it also covers the area corresponding to the Moon; but I believe both these areas are affected principally by the coronal light diffused in our atmosphere, and not to any great extent by ordinary sky light. The green bright line at λ 5303 and a bright line in the ultra-violet are shown on the plate, but all other bright lines seem to be lost in the strong, continuous spectrum of the corona, the dispersion being low. The spectrum of the inner corona appears to be free of absorption-lines. The absorption-lines show very faintly in the spectrum of the outer corona, and still more faintly in the Moon's area. The dark-line spectrum is relatively weaker than on the spectrograms secured in Sumatra (1901) and Spain (1905). The maximum intensity in the continuous spectrum is perceptibly further to the red of the maximum in the solar spectrum obtained with the same instrument,—plainly signifying a lower effective temperature in the corona than in the Sun.

Cramer's isochromatic instantaneous plates were used with the other single-prism instrument. One exposure, from $0^m\ 03^s$ to $0^m\ 20^s$, recorded nothing, no doubt on account of the clouds then prevailing. Another exposure, from $0^m\ 30^s$ to $3^m\ 51^s$, recorded the coronal spectrum very strongly. The description of the corona spectrogram on a Seed plate applies almost exactly to this plate, except that the latter, being isochromatic, records to about λ 6000, all in good focus. The green line extends on either side of the Sun to a semi-diameter, and, in fact, shows faintly across the Moon's band by diffusion in our atmosphere. There is the merest trace of a dark-line spectrum in the violet region.

THE QUARTZ SPECTROGRAPH.

Professor Lewis's large quartz spectrograph, provided for his researches by the Carnegie Institution, was efficient for recording, and determining the accurate positions of, coronal

bright lines. A SCHROEDER's metal mirror, belonging to the Lick Observatory, mounted on a clock-driven (at one half the diurnal rate) polar axis, reflected the light horizontally into the quartz image-lens. The collimator- and camera-lenses of quartz are of 9.2^{cm} aperture and one meter focus. The effective rectangular apertures of the two CORNU quartz prisms are 6×6.8^{cm}. The length of the spectrogram from D to λ 3000 is 14^{cm}.

The slit was adjusted to tangency to the Moon's limb at a point 16° 42′ north of the highest point of the image on the slit, as this was the mean of the positions of tangents to the two points of contact of the Sun and Moon.

It was intended to obtain a spectrum of the first flash, but the rain prevented.

The exposure on the coronal spectrum extended from $0^m\ 15^s$ to $3^m\ 30^s$. The photograph shows a strong continuous spectrum extending from λ 3200 to λ 5100. Here and there in the middle ultra-violet, and nowhere else, are very faint indications of superimposed dark-line spectrum, of the same width as the continuous spectrum. This width is 3.1^{mm}. Superimposed on the continuous spectrum are about twenty-five sharp lines, none of which appears to proceed from the chromosphere. Some are so faint that their existence may be doubtful, while others may be maxima due to the superimposed dark-line spectrum. Two rather strong bright-lines appear to be new. Dr. LEWIS further finds from the photograph that the Sun is relatively much richer in ultra-violet light than the corona, from which fact the much lower effective temperature of the latter is safely inferred.

The west limb of the Moon was made tangent to the slit just at the end of totality, and an exposure on the flash spectrum,—overexposed on account of the duration being shorter than expected,—recorded the tips of some eighty strong, bright crescents projecting beyond the solar spectrum.

A fuller description and discussion of Dr. LEWIS's important results will appear later.

THE POLARIGRAPHS.

The effects of polarization in the coronal light were observed by Dr. PERRINE by means of four special cameras mounted

THE POLARIGRAPHS AND INTRAMERCURIAL CAMERAS.

on a clock-driven axis. There was the camera of 20½ inches focus, having a double-image prism in front of its objective, that was used at the eclipses of 1901 and 1905. The other three cameras, of 50 inches focus, were designed by Dr. PERRINE and used, in 1905, in Spain. Two of these have plane-glass reflectors in front of the objectives to serve as analyzers, while the purpose of the third, pointed directly to the Sun, is to secure an unpolarized image of the corona as a standard of comparison. The aperture of this direct camera was reduced, so that the image obtained with it would be approximately of the same intensity as the (unpolarized) images formed in the other two cameras after reflection from the plane-glass surfaces. The plane-glass analyzers were set at the angle of maximum polarization. Their principal axes were adjusted, one parallel to a north-and-south line and the other to an east-and-west line, through the corona.

The performance of all the polarigraphs was exactly as planned. Mrs. CAMPBELL and Mrs. DREHER assisted in making the observations. The four series of negatives, with exposures of from 2^s to 60^s, appear to be perfect in every respect. They show strong polarization effects in the corona, perhaps even to the very edge of the Moon's image. All of our previous polarization observations were secured through clouds; but, so far as we may judge from a comparison with the present series, the clouds were without appreciable effect on the character of the images.

It is hoped to make accurate photometric measurements of the polarization series of photographs.

THE PHOTOMETER.

Mounted on the same axis as the polarigraphs was a photometer, in all respects resembling an ordinary camera with the lens removed. The light from the corona and surounding sky passed directly through the aperture to the photographic plate. Two plates were exposed when the sky was entirely clear of clouds. Small standard squares on the plates had been exposed to the light of the Hefner lamp on the preceding night. Using these standards as a basis of comparison, it should be possible to obtain a satisfactory measurement of the total effective photographic action of the coronal radiations.

These plates contain the data for measuring the sky brightness surrounding the corona. Dr. PERRINE's examination of the negatives shows that the effective photographic radiations of the corona came almost wholly from its extreme inner parts,—from within 1′ or 2′ of the Sun's surface.

The requirements of a large eclipse expedition are many; but, as I have stated on a previous occasion, the astronomer who is charged with the duty of conducting its affairs is an optimist, for at all points where he needs assistance there are men ready to help him.

The present expedition is under many obligations.

The first reference must be to the great service rendered by the Navy Department of our Government, acting through His Excellency, Captain C. B. T. MOORE, U. S. N., governor of Tutuila, Samoa, who was in command of the U. S. gunboat "Annapolis." To meet us at Tahiti, to transport the expedition to Flint Island early in December, to come a second time to the island, re-embark and carry the expedition back to Tahiti, required an absence of seven weeks from his Samoan post of duty,—an interval but two weeks shorter than our absence from California. Special thanks are due to Governor MOORE not only for the able manner in which the department's instructions were carried out, but for the constant personal and professional attention that he gave to the needs of the expedition and the comfort of its members.

Our cordial thanks are extended also to the able corps of officers of the "Annapolis"—

Lieut. W. G. BRIGGS, U. S. N.
Lieut. H. B. SOULE, U. S. N.
Dr. M. E. LANDO, U. S. N.
Paymaster J. M. HILTON, U. S. N.
Warrant Machinist J. F. GREEN, U. S. N.

The petty officers and the gallant crew rendered splendid and heavy service in transferring our freight twice in Papeete Harbor and twice at Flint Island.

Lever's Pacific Plantations Limited, lessees of Flint Island, gave permission to establish the observing station on the island, and instructed their agents in Papeete, S. R. MAXWELL & Co. (Mr. BUNCKLEY, superintendent), and their successive managers on the island, Messrs. HAWK and MORTIMER,

to meet the requirements of the expedition in every possible manner. Their instructions were carried out most liberally. The native labor was available, at my call, for the landing and re-embarking of the expedition, for the erection of huts, and for many other duties. As previously mentioned, the resources of the bungalow were shared by us for several days, and one room in it was devoted to dark-room purposes. The supply of fresh water was divided with us, half a dozen great turtles were sent in to the commissary department, and a score of other valuable services were rendered by Messrs. HAWK and MORTIMER. Mr. MORTIMER assisted in the observations. We earnestly thank the Lever's Pacific Plantations Limited and their officials, Mr. BUNCKLEY, Mr. HAWK, and Mr. MORTIMER, for the invaluable services that are here but imperfectly mentioned.

The Government of Tahiti, acting under instructions from Paris, kindly expedited the transfer of our freight and baggage through the port of Papeete.

Our country is worthily represented by the American Consul in Tahiti, Dr. JULIUS D. DREHER. During the period of organization he supplied me with reliable information and valuable suggestions on a variety of subjects relating to the work and living arrangements of the expedition. Prior to our arrival he had arranged a score of business matters, in accordance with my statement of needs, which enabled us to proceed promptly to Flint Island. Dr. and Mrs. DREHER were the guests of the expedition during eclipse week, and they assisted in the observations. The pleasures of our nine days at Tahiti were constantly added to by their thoughtful acts of kindness.

Many favors were extended to the expedition by the Oceanic Steamship Company, acting through Captain H. M. HAYWARD, of the steamship "Mariposa," and his officers, through General Passenger Agent COCKROFT, of San Francisco, and through Agent MEUEL, of Papeete.

Mr. J. LAMB DOTY, Mr. F. W. WAKEFIELD, and Mr. and Mrs. F. W. SEARBY, all former residents of Papeete, supplied useful information and advice.

Professor BENJAMIN BOSS, in charge of the U. S. Naval Observatory at Pago Pago, Tutuila, was an efficient member of the expedition throughout our stay of twenty-seven days on **Flint Island.**

C. J. MERFIELD, Esq., of the Sydney Observatory, was a capable and busy member of our expedition during the eleven days that the British party was on the island.

Thanks are extended to Mr. McCLEAN for his generosity in transporting Mr. MERFIELD from Auckland to the island and return, and for the spirit of comradeship and good cheer which he and all the members of his party supplied.

It was a rare pleasure to have Professor LEWIS in our expedition.

The presence of Director ABBOT and Mr. MOORE, of the Smithsonian Institution Expedition, was at all times a happy arrangement. It was a great satisfaction to every member of our party that Mr. ABBOT's scientific plans were carried out exactly as planned.

I gladly acknowledge the able assistance of my colleagues, Messrs. PERRINE, AITKEN, and ALBRECHT, whose services were always available, both in the preparations and at the station. It has been the lot of Dr. PERRINE and myself to be associated in the observation of three eclipses. A veteran of five eclipses, he has no superior as an eclipse observer; and his services, placed unreservedly at my command, were held in high esteem.

A BOLOMETRIC STUDY OF THE SOLAR CORONA.

By C. G. ABBOT.

The Smithsonian Institution was represented among observers of the eclipse of January 3, 1908, by a small expedition including the writer and Mr. A. F. MOORE, of Los Angeles. Our charges were defrayed by the Institution, but we went by invitation and with the co-operation of Director CAMPBELL, of the Lick Observatory, and shared in the benefits of the careful provision which he made for the general welfare and success.

We proposed to measure, with that extremely sensitive electrical thermometer called the bolometer, the intensity of the radiation of the solar corona, and to determine the quality of coronal light as compared with sunlight.